Mid-Frequency Reverberation Measurements with Full Companion Environmental Support

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LONG-TERM GOALS:

To understand mid-frequency (1-10 kHz) acoustics in shallow waters through measurements and modeling, including propagation, reflection, and forward- and backscatter, as well as reverberation. The top-level goals of this effort are to understand the important environmental processes that impact mid-frequency sonar performances in shallow water environments, and to develop means to efficiently collect those environmental data.

OBJECTIVES:

The overall goal is to conduct a reverberation measurement in very shallow water off the coast of Panama City, Florida in FY13, where relevant environmental data will be taken. The frequency range would be 1-10 kHz, emphasizing 3-4 kHz. The Navy relevance is reflected in the fact that detection using mid-frequency sonar is in most cases reverberation limited. The significance of the proposed work is that there is a clear need in both basic research and in applications for a 6.1 level measurement program, but as yet this has not been attempted. Data from such an experiment can be used for testing various forward and inversion techniques because environmental data are available, and can also be used for training purposes.

The water depth of the experiment is in the range of 15-25 m. The relevant water depth for naval applications covers the entire continental shelf. The key issue for reverberation is small grazing angle propagation and scattering in a waveguide. The major burden of such an experiment program is measuring the environment that influences reverberation. Reducing the region over which the environment needs to be measured becomes a primary consideration. By reducing the water depth to 15-25 m, the range at which the sound field is dominated by small grazing angle propagation and scattering is shorter than at deeper depths. Therefore, environmental measurements can be limited to a smaller area. Another advantage of working in such water depths is that diver support at the bottom is available, which provides added control of the various measurements. Finally, from an environmental standpoint, the shorter ranges allow lower source levels to be used,and therefore the measurement program can be more easily made compatible with environmental regulations.

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Propagation and Scattering mechanisms to be addressed: Bottom roughness (including ripples); water column variability, including internal waves, that affects propagation; surface roughness as a function of wind speed; fish school properties, and known clutter such as a ship wreckage and artificially released bubbles to mimic fish swim bladders.

Supporting Environmental Measurements: Along the propagation path, sediment geo-acoustic parameters to a depth of 2-3 m; bottom roughness with depth resolution of 1 mm and range resolution of 1 cm; water column sound speed field over time; sea surface roughness as a function of time; and presence of fish schools and their characteristics over time.

APPROACH

This effort is collaboration with PI's funded by ONR OA from many institutions. Collaborators from APL-UW include Brian Hefner, Kevin Williams, and Eric Thorsos, whose work in FY11 is closely related to that reported here.

Instead of using omni-directional transmit and receive transducers, we propose to use a horizontal receive array with starboard/portside discrimination such that only a 2 degree wedge-shaped ocean needs to be measured for environmental support. A possible candidate array is the ONR FORA. It has a high-frequency triplet horizontal aperture of 15.6 m, and is cut for a center frequency of 3750 Hz. Its beam width is less than 2 degrees. Another possibility is to use the dedicated mid-frequency array proposed by the ONR Ocean Acoustics community (John Preston, POC).

In April,2011, an engineering test, GulfEx11, was conducted at 20 m depth off Panama City, Florida, with the primary goal of testing the SAMS system for measuring sediment sound speed. Taking advantage of this opportunity, we also accomplished several relevant objectives:

1. Geoacoustic survey with John Goff
2. Multibeam bottom classification with Christian Demoustier
3. Preliminary reverberation data set on a 32 element horizontal array
4. Sample bottom roughness data (Hefner)
5. Sample backscatter data
6. Support participation in GulfEX11of three scientists from India

WORKCOMPLETED

1. Completion of GulfEx11 with multiple acoustic and environmental data sets to be analyzed to support the main experiment in FY13
2. Data analyzed on SAMS data sets and on backscatter
3. Development of a model to simulate reverberation
4. Development of a numerical modeling capability to simulate normal incident sonar output such as a chirp sonar.

RESULTS

1. The main goal of GulfEx11 is to test SAMS system for measuring sediment sound speed. Both mechanical and electrical systems worked properly but the system had difficulty penetrating shell layers which have been found to be extensive at the experimental site. A revision of the system to overcome the shell layers has been proposed under a new DURIP proposal. A maximum sediment penetration depth of 1.9 m was achieved. A full calibration of the system was performed to understand multipathing from SAMS's structure (Fig. 1). In the frequency band of 1 – 12 kHz, sound speed was found in the range of 1688 ± 40 m/s using SAMS.

2. One important question for the FY13 reverberation experiment is to determine what is the main bottom scattering mechanism, i.e., surficial roughness vs. subbottom heterogeneity. During GulfEx11, backscatter data were taken at both 3-4 kHz and 9-10 kHz band. Fig. 2 shows the measured scattering strength andits uncertainties as a function of grazing angle and is compared to the Lambert scattering strength. This is later to be compared to bottom roughness data to determine if the roughness dominates backscatter at this site. What is needed is more measurements toward smaller grazing angle, because reverberation is a caused by very small grazing angle backscatter.

3. A theoretical model was developed (with Jackson) to simulate mid-frequency reverberation in range-dependent environments. Now we are concentrating on expanding the simulation to include multiple receivers on a line array.

4. Downward looking sonar, such as the chirp sonar, is used widely as a sediment survey tool in shallow water environments. Inversion of goeacoustic parameters from such sonar data precedes the availability of forward models. An exact numerical model wasdeveloped to initiate simulation of the acoustics field produced by such sonar in the presence of multiple rough interfaces.

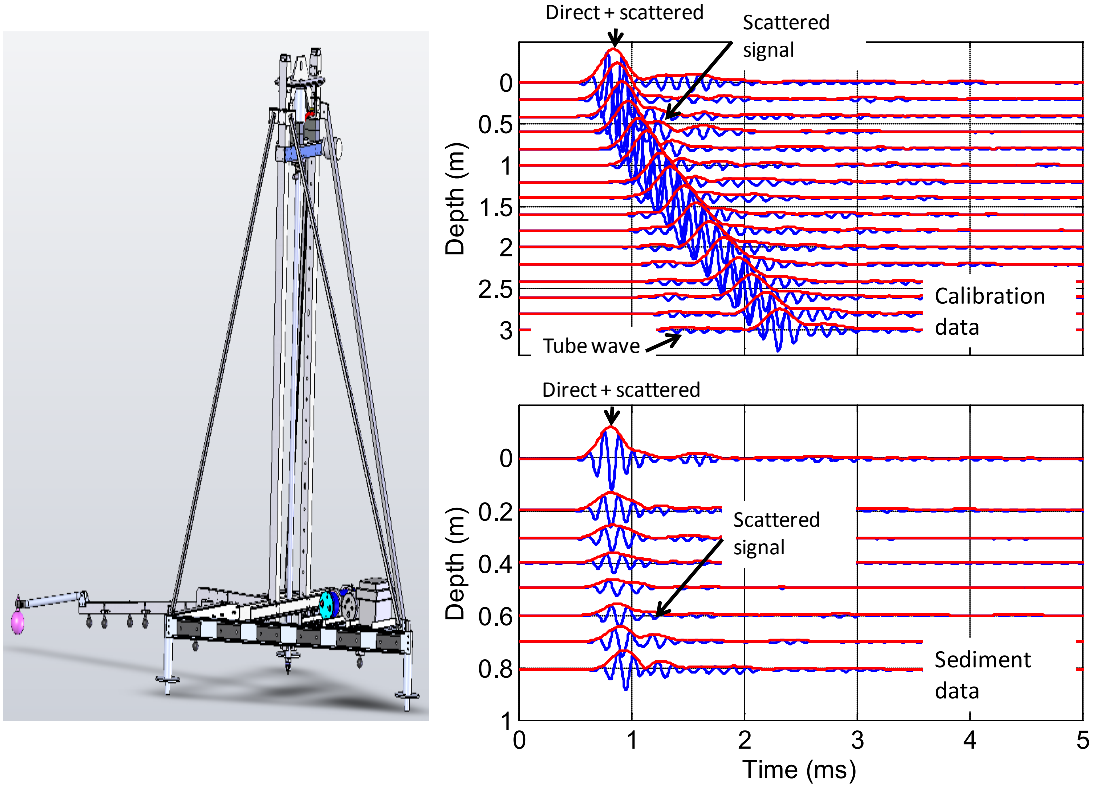

Figure 1 Left: SAMS; top right: calibration data taken March 2011 showing complications of scattered signal from on-frame battery box and tube wave; bottom right: data taken when SAMS penetrated the sediment to 0.8 m. Frequency band: 1 – 12 kHz.

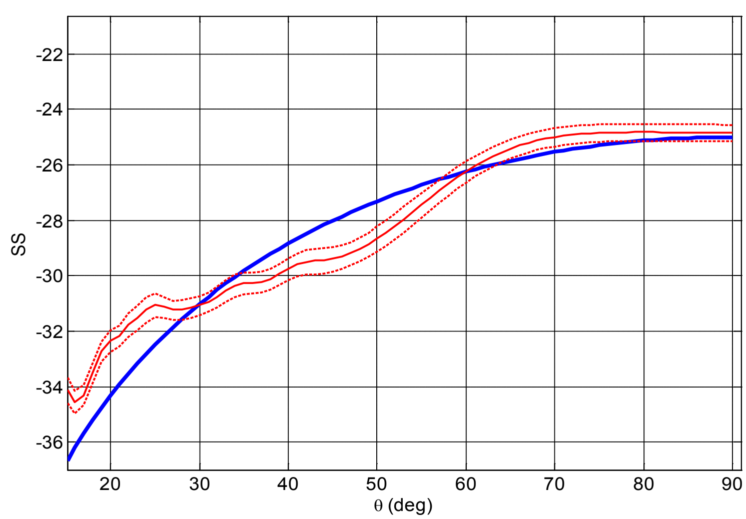

Figure 2 Measured bottom scattering strength vs. grazing angle at 3-4 kHz. Red solid: mean strength, red dash: uncertainty, blue solid, Lambert SS.

IMPACT/APPLICATIONS

Naval active sonar detection is often reverberation limited. Understanding the main mechanism that causes the defused reverberation is lead to better sonar performance. We anticipate impacts in the following areas: first, the data set taken in GulfEx11 will help the design of the planned Reverberation Field Experiment in FY13. The environmental data, such as the SAMS data, the surficial roughness data, the vibracore data and chirp survey data will have direct application to the measurement, modeling, and interpretation of the reverberation. The acoustics measurements in GulfEx11 greatly improve our understanding of the site for the FY13 experiment. The modeling capability will assist the planning of the reverberation experiment, and analysis of the experimental data. All these efforts are aimed at the main goal of understanding the question of what environmental factors are driving reverberation.

RELATED PROJECTS

ONR reverberation workshop series (Thorsos and Perkins)

ONR applied reverberation workshop series (Holland)

ONR MCM projects

PUBLICATIONS

1. Jie Yang, Darrell R. Jackson, and Dajun Tang, “Mid-frequency geoacoustic inversion using bottom loss data from the Shallow Water 2006 Experiment”, J. Acoust. Soc. Am. (accepted).
2. Tang, D., and D. R. Jackson, “Application of Small-Roughness Perturbation Theory to Range-Dependent Waveguides,” J. Acoust. Soc. Am., (under review).
3. Tang, D., and B. T. Hefner, “Modeling backscatter from a series of sediment rough interfaces by a normal incident chirp sonar,”J. Acoust. Soc. Am., (In preparation).
4. Tang, D., F.S. Henyey, D. Rouseff, and J. Yang, “Single-path mid-frequency acoustic intensity fluctuations in shallow water, ”J. Acoust. Soc. Am., (In preparation).
5. Henyey F., K Williams, J. Yang,and D. Tang, “Simultaneous nearby measurements of acoustic propagation and high-resolution sound speed structure containing internal waves,” *IEEE J. of Oceanic Engineering*, Vol. 35, 684-694 (2010).
6. Yang, J., D. Rouseff, D. Tang, and F. S. Henyey, “Effect of the internal tide on acoustic transmission loss at mid-frequencies”, *IEEE J. Oceanic Engineering,*Vol. 35, 3-11 (2010).